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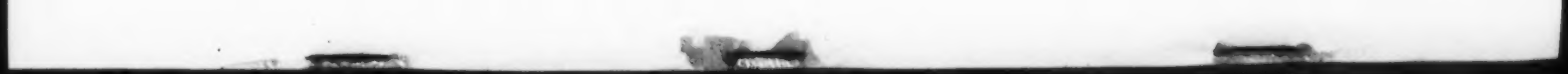

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THE NATURE OF ABSORBING MATERIAL WITHIN THE GALAXY AND ITS INFLUENCE ON ESTIMATES OF GALACTIC DIMENSIONS*

By C. S. BEALS

THE existence of absorbing material in interstellar space, as indicated by the presence of dark markings and bands of obscuration on stellar photographs, has been known for over fifty years, but it is only comparatively recently that its influence on the measurement of galactic distances has been fully realized. Much of the early work on stellar distances was concerned with relatively close stars where the absorption was inappreciable. As astronomers pushed their investigations farther and farther into space, however, the existence of absorbing material and its effect on observations of stars became more and more apparent until now it is recognized as one of the major problems of astrophysics.

Terrestrial Photometry. Some of the more important aspects of the problem may be illustrated by an example taken from terrestrial physics. All physicists are familiar with the use of standard lamps for the purposes of photometric investigation. Once the candle power or intrinsic luminosity of a standard lamp has been accurately determined, it would be possible by a simple application of the inverse square law of brightness to make use of such a source for the measurement of terrestrial distance.

The principal obstacle to the use of such a method would be lack of perfect transparency in the earth's atmosphere, which

*The second of three papers constituting a symposium of the Section of Physical Sciences of the Royal Society of Canada at Kingston, Ont., May 22, 1945.

almost always contains a certain amount of smoke and haze and which would tend to invalidate the application of the inverse square law.

A physicist would not ordinarily make use of such a method to measure distances on the earth's surface, since a number of better methods are available to him. He can, however, and frequently does reverse the procedure, measuring the distance by the conventional methods familiar to every surveyor and then making use of his standard lamp and the departure from the inverse square law to determine the absorbing qualities of the atmosphere.

Intrinsic Luminosities of Stars. In studies of the galaxy very similar problems are encountered and similar methods are used to solve them. During the past few decades a very great amount of labour has been expended on methods for the determination of standard celestial light sources, that is stars whose intrinsic luminosities can be determined independently of their distances. At first sight this might appear to be so difficult a task as to be impossible but actually two independent and reliable methods have been developed to accomplish it.

The first method involves a study of the relation of the spectrum of a star to its output of radiation. As a result of many thousands of observations it has been demonstrated that the rate at which an individual star gives out light energy is directly related to its spectrum, so that, within reasonable limits of error, the intrinsic luminosity can be determined by a study of the spectral line intensities and their relation to the density and state of ionization of the star's atmosphere.

The second method, already dealt with by Mrs. Hogg,* involves, for certain interesting types of variable stars, a relation between the period of variation and the intrinsic luminosity. In the case of these objects (which are known as Cepheid variables), a knowledge of the period of light-variation leads at once to the intrinsic luminosity, and as a consequence these stars are among the most important in the sky for the purpose of estimating galactic distances or for determining the effect of absorbing material on the apparent brightness of stars.

*In the October issue, p. 289.

Stellar Distances and Values of the Absorption Coefficient. With adequate means available for fixing the intrinsic luminosities of stars the problem of absorbing matter in the galaxy further requires for its solution sufficiently reliable methods of measuring distance. Fortunately there are available a number of methods of determining stellar distances which are independent of the inverse square law. Two only will be mentioned here.*

The first is the very ingenious method devised by Trumpler[1] of estimating the distances of open galactic clusters like the Pleiades by observing their apparent diameters. Obviously such a group of stars will appear smaller the farther it is away and by making use of this principle Trumpler has determined the distances of 100 clusters ranging in distance from 39 to 2540 parsecs. Each cluster contains many stars and by selecting a few of the brightest in each it was found possible to make observations of their spectra and so to determine their intrinsic luminosities. A comparison of the apparent and intrinsic luminosities showed that in nearly all cases there were departures from the inverse square law of brightness which indicated the presence of absorbing material in interstellar space. Mean values for the absorption coefficient indicated a value of 0.8 stellar magnitudes per thousand parsecs. On this basis the apparent brightness of a star at a thousand parsecs distance would be observed to be somewhat less than half its value in the absence of absorption.

A second and even more powerful method of estimating stellar distances was made available as a result of the study of the effect of galactic rotation on the radial velocities of stars. This aspect of the subject will be fully treated by Dr. Pearce in the next paper and here it is only necessary to say that by the use of the familiar equation[2]

$$\rho = \bar{r} A \sin(l - l_o) \cos^2 b,$$

where ρ = radial velocity of group of stars with solar motion removed,
$\bar{r}$ = mean distance of a group of stars,
A = constant of rotation, 0.017 km/sec. per thousand parsecs,
l = galactic longitude of group of stars,
l_o = galactic longitude of galactic centre,
b = galactic latitude of group of stars,

*Trigonometric methods on which all systems of measuring stellar distance are ultimately based cannot be used for such distant stars as are involved in the present discussion.

it is possible to obtain reliable values of the mean distances of groups of stars, particularly such distant stars as may be inaccessible by other methods.

Joy[3] made use of this method to estimate the effect of absorption on a selected list of galactic Cepheids ranging in distance from 120 to 12,000 parsecs. With the aid of intrinsic luminosities derived from periods of light variation, he was able to show that the average effect of absorption was 0.85 magnitude per thousand parsecs, in good agreement with Trumpler's previous work.

Later Wilson,[4] making use of all known stars whose distances had been determined by galactic rotation methods, and using both Cepheid variation and spectral type as criteria of intrinsic luminosity, derived a value for the average absorption in the galaxy of 0.75 stellar magnitudes per thousand parsecs in photographic light, in very good agreement with the figures of Trumpler and Joy previously quoted.

All three observers agreed that the distribution of absorbing material was far from uniform and that the adopted value (which may be set at 0.8 magnitude per thousand parsecs within the limits of error of the observations) would only be a rough average for the volume of space investigated, with larger and smaller values for localized regions. An interesting and important consequence of the above determination of the coefficient of absorption was that the inverse square law of brightness could again be applied to the statistical investigation of stellar distances provided the necessary corrections were applied, the appropriate expression being

$$M = m + 5 - 5 \log D - 0.0008\, D,$$

where M = absolute magnitude,
m = apparent magnitude,
D = distance of star in parsecs.

Before leaving the matter of the coefficient of general absorption it may be interesting to give the following three examples of the effect of absorbing matter on the apparent brightness of distant stars in the galactic plane. For a star at 1000 parsecs the apparent brightness is reduced to somewhat less than one half by absorption. At 3000 parsecs the apparent brightness is one-ninth what it would be in transparent space. At 8000 parsecs, approximately the distance of the galactic centre, a star is reduced to 1/360 of its normal brightness. When to these effects are added the normal

diminution of brightness due to the inverse square law, it is easy to see why the great majority of stellar observations in the galactic plane are restricted to distances of a few thousand parsecs. It is very reasonable to suppose that the density of absorbing matter may increase in the direction of the galactic centre, approaching complete opacity, so that stars at that distance in the central plane are invisible to us.

Disc-Like Distribution of Absorbing Matter and Derivation of its Optical Thickness from Counts of Nebulae. In a brief review it is not possible to discuss in detail all the steps leading to our present-

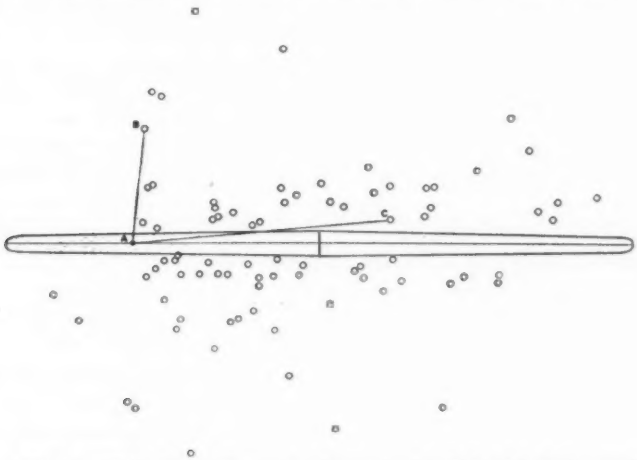


Fig. 1.—This figure illustrates the general relationship between the disc-like distribution of absorbing material and the system of globular clusters. It is immediately apparent that for an observer at *A* the light from cluster *C* will suffer greater absorption than the one at *B*, while clusters closer to the galactic plane than *C* will be still further diminished in brightness.

day picture of the distribution of absorbing material in the galaxy. It is believed to coincide in a general way with the distribution of the stars themselves and to occupy a disc-shaped volume, very thin compared to its diameter. The solar system is far from the centre of the disc, rather more than half way from the centre to the edge. The optical thickness for directions in the plane of the disc

is very great, resulting in complete obscuration at great distances. As a consequence such external objects as spiral nebulae and globular clusters do not appear for a certain angular distance of about five degrees on either side of the galactic plane. From Fig. 1 it is clear why this should be so and it is further obvious that any object external to the galaxy, regardless of direction, must suffer some diminution of brightness due to absorption by material within the disc-like volume outlined by the galactic boundaries.

The quantitative investigation of this effect and its dependence on galactic latitude was carried out in a series of brilliant investigations by Shapley,[5] Hubble,[6] and van de Kamp,[7] dealing with counts of extra-galactic nebulae. It was demonstrated by them that the number of spiral nebulae per square degree was greatest near the pole of the galaxy and fell off with decreasing galactic latitude according to a cosecant law, until it reached zero in the so-called region of avoidance near the galactic plane. This phenomenon was clearly a consequence of absorption of material within the galaxy and a relatively simple mathematical treatment of the data leads to a value of the total absorption from pole to pole. Hubble's result was 0.5 magnitude while van de Kamp, making use of Shapley's counts of nebulae, derived a value of 0.8 magnitude. On the basis of estimates of the galactic absorption coefficient of 0.8 magnitude per thousand parsecs this would indicate that the total thickness of the absorbing stratum was probably somewhat less than 1000 parsecs.

The above results from counts of nebulae were later confirmed by Stebbins and Whitford[8] from data on the colours of globular clusters measured with the aid of a photo-electric cell. In agreement with results derived from counts of nebulae they found that the reddening of the clusters was greatest close to the galactic plane and that the numerical values of the colours was related to the galactic latitude by a similar cosecant law.

Effect on Distances of Globular Clusters. On the basis of the above numerical results of a total absorption from pole to pole of 0.5 to 0.8 magnitude it is now possible to make use of the cosecant law to re-investigate the distance to the centre of the globular cluster system on which the original estimates of the dimensions of the galaxy were based. A general idea of the distribution of the

globular clusters was given in the preceding figure. Most of the observed clusters are more than 5° from the galactic plane and therefore probably outside the disc-like volume occupied by the obscuring matter. They are believed to be symmetrically distributed about the centre of the galaxy so that a determination of the distance of the centre of the globular cluster system leads to an estimate of the dimensions of the galaxy as a whole.

The original estimates of the distances of the globular clusters were based on the inverse square law and the assumption of transparent space. The standard light sources were Cepheid variable stars of short period which are a common feature of globular

TABLE I

ESTIMATES OF DISTANCE TO CENTRE OF GALAXY

Photographic Optical Thickness from pole to pole	Distance to Centre of Galaxy	Basis
Magnitudes	Parsecs.	
0.0	16,400	Shapley, Transparent Space
0.32	10,000	Stebbins and Whitford, Colours of Clusters
0.50	8,000	Hubble, Counts of Nebulae, Mt.W.
0.80	5,500	van de Kamp, Counts of Nebulae, Harvard

clusters. The nature of these stars is such that a considerable degree of confidence can be placed in the accuracy of the intrinsic luminosities and a corresponding amount of confidence was placed in the derived distances. The distance to the centre of the globular cluster system originally due to Shapley was 16,000 parsecs leading to a total diameter of the galaxy of the order of 85,000 parsecs.

Corrections for the effects of absorption have radically altered this result. As an example we may consider the case of a cluster having a galactic latitude of 5°. Assuming an optical thickness of 0.65 magnitude for the absorbing layer the correction factor for the distance of the cluster becomes

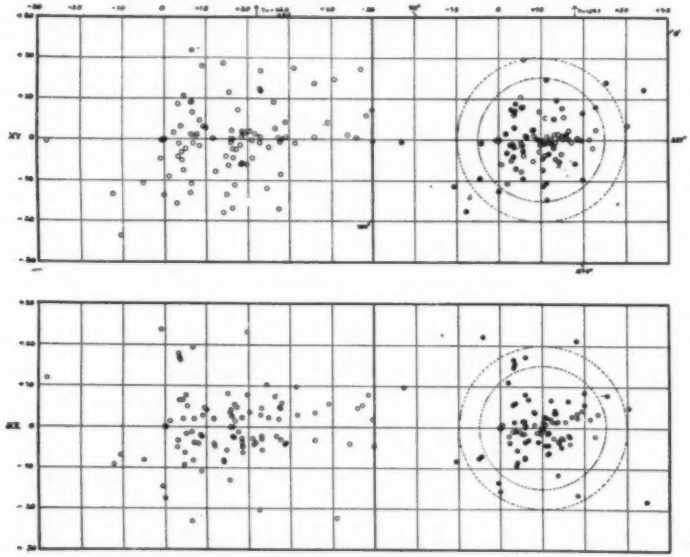
$$\log f = -0.065 \operatorname{cosec} b,$$

and

$$f = 0.18.$$

That is, the original estimate of distance based on the inverse square law would be too large by a factor of 5.55. Actually most

of the clusters are farther from the plane and the corrections to their distances are less drastic. The accompanying Table 1 due to Stebbins and Whitford indicates that the distance from the solar system to the centre of the galaxy has been reduced to approximately one half while the total dimensions of the galaxy have been reduced from approximately 85,000 to 33,000 parsecs.



DISTRIBUTION OF GLOBULAR CLUSTERS WITH AND WITHOUT CORRECTION FOR ABSORPTION

Fig. 2.—These diagrams due to Plaskett and Pearce graphically illustrate the change in our ideas of galactic dimensions brought about by correcting for absorbing matter in the galaxy. The distribution of globular clusters represented on the left in the *XY* and *XZ* planes corresponds to the assumption of transparent space. On the right is shown the corresponding distribution after correction for space absorption. The co-ordinates are given in thousands of parsecs.

The same result is graphically illustrated in Fig. 2, due to Plaskett and Pearce, showing the known globular clusters projected on the plane of the galaxy, first as described by Shapley, and then as modified on the basis of absorption by Stebbins and Whitford.

As will be pointed out later by Dr. Pearce, the new estimate of galactic dimension is in satisfactory accord with values derived from galactic rotation, and the mutual confirmation given by the two methods lends confidence to the final result. One of the most interesting and logically satisfactory consequences of this development is that our galaxy no longer need be regarded as unique among the spirals. The revised dimensions make it comparable in size to the Andromeda Nebula and other large extra-galactic systems; in other words, a normal member of the vast population of galaxies which inhabit infinite (?) space.

Nature of Absorbing Material. Any inquiry as to the nature of the material responsible for general obscuration in the galaxy is presented with two very definite alternatives. The absorption must be due either to finely divided solid particles or to gas. Some inkling as to which alternative is the correct one may be drawn from terrestrial experience. All are familiar with the remarkable transparency of the earth's atmosphere on a clear day. If smoke or dust is present, however, even though its total mass may be infinitesimal in comparison with the atmospheric gas which supports it, the transmitted light of the sun may be reduced to a minute fraction of its original intensity. Even such a rough observation as this gives a clear indication of the great absorbing power of solid particles as compared with the gases of the air.

Theoretical investigations also support the conclusion that finely divided solid particles are enormously more efficient than gas molecules in absorbing light. Trumpler[1] has pointed out that the density of gas required to produce an absorption coefficient of 0.8 magnitude per thousand parsecs is hundreds of times greater than the mean density of the galaxy due both to stars and interstellar matter.* On the other hand it has been known for many years that solid particles of the order of size of the wave-length of light or even considerably larger are capable of producing the observed absorption effects without even approaching the limits of density set by the known dynamical properties of the galaxy[9].

The conclusion is, therefore, that the absorption is due to solid particles and this conclusion is further reinforced by data on the selective absorption of the light of distant stars. Reddening due to absorption by gaseous molecules is of the so-called Rayleigh

*The best modern estimate due to Oort is 6×10^{-24} gm. per cc.

type where the coefficient of scattering is inversely proportional to the fourth power of the wave-length. Actual observations indicate a much less drastic reddening and numerous observers[10] agree that the actual law of scattering is not far from λ^{-1}. Such a law of scattering could only be caused by solid particles of many times the wave-length of light and therefore of an entirely different order of size from gas molecules. From various converging lines of evidence[11] it is now considered that the diameter of the most numerous particles is of the order of 10^{-5}cm. The frequency distribution is as yet unknown although it is reasonable to suppose that it ranges from the dimensions of meteorites down to particles approaching the size of gas molecules.

Atoms in Interstellar Space. Although it is now certain that the major obscuration effects in the galaxy are due to clouds of solid particles, gases are also known to be present and to constitute an important fraction of the total galactic mass. The earliest indications of the presence of gases were found in the bright lines due to atoms of hydrogen and helium in the diffuse nebulae[12]. Of more importance to our present discussion, however, is the appearance of fine narrow absorption lines of interstellar origin due to sodium, ionized calcium and other atoms in the spectra of early type stars[13]. The interstellar origin of these absorption lines has been demonstrated both by their increase in intensity with distance and by the fact that they do not share the Doppler displacement shown by the stellar lines of spectroscopic binaries and high-velocity stars. Also, since they are ordinarily observed only in the spectra of early type stars with relatively broad lines, they can usually be identified immediately by their narrow line character.

For many years the only absorption lines known to be due to interstellar matter were the CaII lines H and K, and the sodium doublets at λ5890-96 and λ3302.3-3302.9. More recently, due to the use by the Mount Wilson observers of higher dispersion and to the extension of the observations to the infra-red and ultra-violet regions of the spectrum, new lines due to TiII, FeI, CaI, and KI have been discovered. Additional lines due to OII, OIII, NII and H appearing in emission have been found by Struve[14] and his collaborators to be characteristic of the general sky light in certain regions of the Milky Way and if we accept the evidence given by

the emission line spectra of the diffuse nebulae still other lines due to Ne, C, He, Si and S must be added to the list of those almost certainly present in interstellar space. Actually there is now every reason to suppose that most if not all the atoms constituting the material of the earth's crust and the stars are also present in interstellar space even though only a few atoms having ultimate lines in the observable region have so far been identified. A list of atomic interstellar lines is given in Table II.

Interstellar Molecules. All atomic interstellar lines so far observed arise from the lowest level of the atom, even sub-levels of

TABLE II

INTERSTELLAR LINES OF ATOMIC ORIGIN

Absorption Lines			Emission Lines		
Atom	λ	Multiplet	Atom	λ	Multiplet
NaI	3302.38	$3^2S - 4^2P^0$	H	4340.48	$2^2P^0 - 5^2D$
NaI	3302.98	$3^2S - 4^2P^0$	H	4861.34	$2^2P^0 - 4^2D$
NaI	5889.98	$3^2S - 3^2P^0$	H	6562.81	$2^2P^0 - 3^2D$
NaI	5895.94	$3^2S - 3^2P^0$	OII	3726.12	$a^4S^0 - a^2D^0$
KI	7664.88	$4^2S - 4^2P^0$	OII	3728.91	$a^4S^0 - a^2D^0$
KI	7698.98	$4^2S - 4^2P^0$	OIII	4958.91	$2p^3P - 2p^1D$
CaI	4226.74	$4^1S - 4^1P^0$	OIII	5006.84	$2p^3P - 2p^1D$
CaII	3933.68	$4^2S - 4^2P^0$	NII	6548.1	$2p^3P - 2p^1D$
CaII	3968.49	$4^2S - 4^2P^0$	NII	6583.6	$2p^3P - 2p^1D$
TiII	3072.97	$a^4F - z^4D^0$			
TiII	3229.18	$a^4F - z^4F^0$			
TiII	3241.97	$a^4F - z^4F^0$			
TiII	3383.78	$a^4F - z^4G^0$			
FeI	3719.95	$a^5D - z^5F^0$			
FeI	3859.92	$a^5D - z^5D^0$			

extremely low excitation being, apparently, depopulated by forbidden transitions. From this it may be inferred that in searching for interstellar molecules it would be useless to expect the extended band structures commonly observed in laboratory or stellar spectra. Only lines arising from the lowest rotational levels of the normal state of the atom would be likely to appear so that each "band" as observed in the laboratory would be represented by one or more isolated narrow lines which could only be distinguished from atomic absorption by measurements of wave-length or relative intensity.

McKellar[15] has determined from laboratory data the wavelengths to be expected from a number of such common molecules as would be likely to be present in interstellar space and with the aid of observations by Adams[16] four lines due to CH and three due to CN have been definitely identified. More recently three more lines observed by Adams have been identified as due to CH^+ by Douglas and Herzberg[17]. All the molecular lines so far observed are very faint and it is probable that greater telescopic power and higher dispersion would result in many more discoveries. A list of the known molecular lines appears in Table III.

Structure of Interstellar Lines. When observed with spectrographs of moderate dispersion, interstellar lines due to known atoms and molecules appear exceedingly sharp and fine, comparable

TABLE III

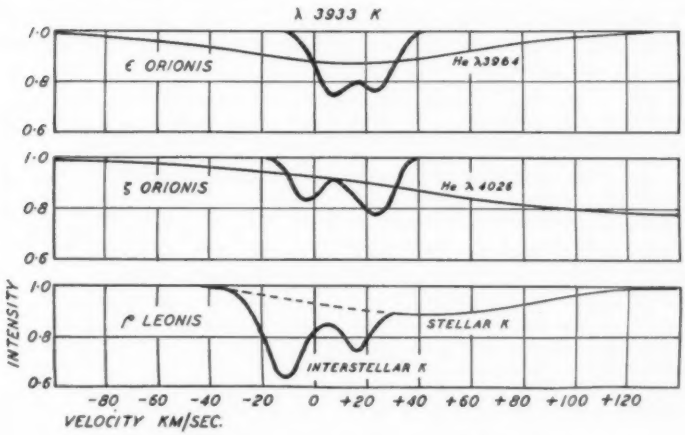
INTERSTELLAR ABSORPTION LINES OF MOLECULAR ORIGIN

Molecule	Line	Interstellar λ	Lab. λ
CH	$R_2(1)$	4300.34	4300.31
CH	$_PQ_{12}(1)$	3890.25	3890.23
CH	$Q_2(1) + {}_QR_{12}(1)$	3886.44	3886.39
CH	$R_2(1)$	3878.81	3878.77
CN	P(1)	3875.77	3875.77
CN	R(0)	3874.62	3874.61
CN	R(1)	3874.02	3874.00
CH^+	R(0)	4232.58	4232.57
CH^+	R(0)	3957.72	3957.71
CH^+	R(0)	3745.33	3745.30

in this respect to the lines of the comparison spectrum. It was accordingly a matter for surprise when high dispersion (4.5 A. per mm.) spectrograms of the star ρ Leonis secured at Victoria in 1936 revealed that the interstellar lines H and K were double with a separation of the components of 27 km/sec.[18] Later double H and K lines were also observed in the spectra of ϵ and ζ Orionis while subsequent observations in the visible region showed a similar structure of the interstellar lines of sodium[19]. The double interstellar lines of these stars are illustrated in Fig. 3 and 4.

These observations suggested the presence in interstellar space

of discrete clouds of absorbing gases having relatively large peculiar velocities relative to one another. This interpretation received brilliant confirmation from later work at Mount Wilson where Adams[20] obtained spectrograms with a Coudé spectrograph which revealed in some cases as many as five components to a single interstellar line with a velocity range of over 60 km./sec. Adams' observations which covered fifty stars, indicated that complex structure was the rule rather than the exception for interstellar lines. This gave further confirmation to the general idea that the



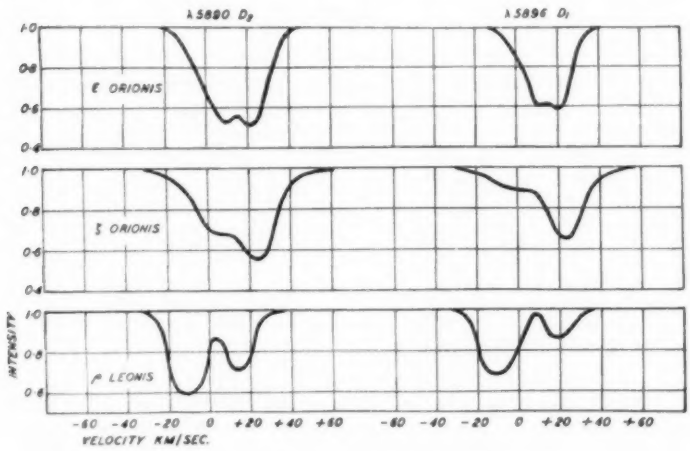
DOUBLE LINES OF INTERSTELLAR CALCIUM

Fig. 3.—Double lines of interstellar calcium compared with stellar lines. For the stars ϵ and ζ Orionis, helium line profiles are superimposed upon the calcium lines to illustrate the difference in width. For ρ Leonis a similar purpose is served by stellar *K* which is observed to be blended with the interstellar line.

gaseous material of the galaxy, instead of evenly pervading the spaces between the stars, was discontinuously distributed with numerous cloudlike masses of enormous dimensions, perhaps analogous in some respects to the great star clouds of the Milky Way. While the peculiar motions of such clouds are revealed by the structure of the interstellar lines, there is superimposed upon them also the motion of rotation of the galaxy, an aspect of the

subject which will be discussed in detail by Dr. Pearce in the following paper.

Unidentified Interstellar Lines. Of the numerous sharp interstellar lines which have been observed, only two remain unidentified and it is reasonably certain that their origin will ultimately be found to be due to gaseous atoms or molecules. There exists however a group of additional features of quite different character whose origin presents much more of a puzzle. These lines, which were discovered by Merrill[21], are from 10 to 40 angstroms in width and present a remarkable contrast in appearance to the sharp lines. Profiles of a number of these lines are shown in Fig. 5, where they are compared to a sharp interstellar line due to the



DOUBLE LINES OF INTERSTELLAR SODIUM

Fig. 4.—Double lines of interstellar sodium corresponding to the double calcium lines of Fig. 3. The close correspondence in form of the sodium and calcium lines leaves little doubt of their interstellar origin.

molecule CH^+. A list of the broad lines will be found in Table IV. The conclusion that they are due to interstellar absorption rests on their increase in intensity with distance and the fact that they do not share the large variations in velocity shown by spectroscopic binaries.

The only suggestion so far put forward to explain them is that they may be due to absorption by solid particles. It is well known that many solid substances exhibit discontinuous absorption and have lines or bands associated with them. Such a suggestion for identification is rendered more attractive by the apparent impossibility of accounting for the broad lines by an atomic or molecular origin. So far there is no confirmatory evidence from the laboratory to support such an hypothesis but the absorption spectra of solids are not too well known and it is possible that future laboratory discoveries may bring to light interesting new information which may bear on the nature of interstellar particles.

TABLE IV

UNIDENTIFIED INTERSTELLAR LINES

Diffuse Lines		Sharp Lines	
λ	Int.	λ	Int.
4430.6*	10	3579.04†	0
4760**		3934.3††	0
5780.55	3		
5797.13	1		
6202.99	1		
6269.99	1		
6283.91	6		
6613.9	2		

*The indication of intensity reflects the equivalent width of this line. The actual existence of the line is frequently difficult to detect because of its great width and small central depth.

**A broad feature tentatively identified by Merrill as an interstellar line. (Private communication.)

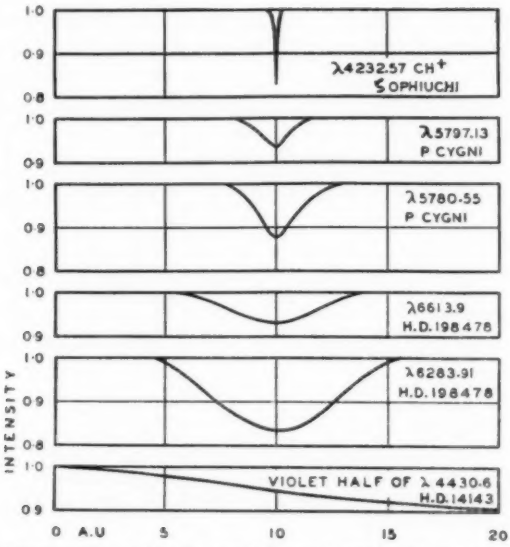
†May be due to 3.0 band of CH^+ system.

††May be due to NaH (P.A.S.P., vol. 52, p. 307, 1940 and Ap.J., vol. 93, p. 11, 1941.)

Density of Interstellar Matter. The density of interstellar matter presents a problem of great difficulty. Dynamical considerations due to Oort [22] give an upper limit of 6×10^{-24} gm. per cc. for the density of the galaxy as a whole, but the partition of mass between stars and interstellar matter cannot be accurately determined by this method.

Greenstein[23] has derived a value of the mean space density of

solid particles from a consideration of the frequency distribution of diameters of hyperbolic meteors (meteors from outside the solar system). His result of 2×10^{-25}gm. per cc. is probably the best available at the present time but since a large extrapolation to smaller diameters is involved it can scarcely be regarded as more than a tentative estimate.



Comparison of Broad and Narrow Interstellar Lines

Fig. 5.—Profiles of five broad interstellar lines compared with a narrow molecular line of comparable central depth. The profiles of the broad lines seem inconsistent with a gaseous origin and the possibility has been suggested that they may be due to absorption by solid particles.

Values of the densities of interstellar gases are probably more reliable since they depend upon measured intensities of absorption lines combined with knowledge of atomic constants and the state of ionization of interstellar matter. Table V contains results by Dunham and Struve for absorption and emission lines respectively. This table suggests that the interstellar gas consists mainly of

TABLE V

DENSITY OF GASES IN INTERSTELLAR SPACE

Atom	Density (Dunham)	Density (Struve)
Hydrogen	1.7×10^{-23}	2.7×10^{-24}
Oxygen	....	2.3×10^{-26}
Sodium	4×10^{-27}	4×10^{-29}
Potassium	7×10^{-28}	....
Calcium	7×10^{-28}	7×10^{-30}
Titanium	8×10^{-30}	....
CH	2×10^{-29}	....
CN	1.5×10^{-29}	....

hydrogen and that its density approaches or exceeds Oort's limit of 6×10^{-24} gm. per cc. for the density of the galaxy as a whole, due both to stars and interstellar matter. If these results are accepted as valid it follows that the contribution of interstellar gas to the galaxy may be equal to or greater than the combined mass of the stars.

SUMMARY

Studies of absorbing matter within the galaxy, making use of absolute magnitudes derived from line spectra and Cepheid variability, and of stellar distances derived from studies of open cluster diameters and galactic rotation, have indicated an average coefficient of absorption of 0.8 magnitude per thousand parsecs.

Analyses of the relation between the apparent distribution of extra-galactic nebulae and galactic latitude have led to a value of 0.65 magnitude for the total absorption of the absorbing material from pole to pole for that part of the galaxy where the sun is located. A similar analysis of the colours of globular clusters leads to considerably smaller values. The linear thickness of the disc-like distribution of absorbing matter is probably of the order of 1000 parsecs.

The original estimates of the distances to the centre of the globular cluster system indicated a total diameter of the galaxy of the order of 70,000 to 100,000 parsecs. Corrections for the effect of absorption have reduced this to the order of 33,000 parsecs, making our galaxy comparable in size to the larger extra-galactic nebulae.

Studies of the relative absorbing power of gas and solid particles

have shown that the major obscuration effects in the galaxy are due to finely divided solid matter, with the most numerous particles having diameters of the order of 10^{-5} cm.

Interstellar gas is also known to be present as indicated by the presence of both absorption and emission lines. Numerous lines due to common atoms and molecules have been identified and it is probable that the chemical constituents of the interstellar gas are similar to those of the earth's crust and the atmospheres of the stars.

Estimates of the density of interstellar matter indicate that it is probably due mainly to gaseous molecules, the solid particles making a relatively small contribution. The total mass of the absorbing material may well be equal to or greater than the combined mass of the stars.

REFERENCES

[1]Trumpler, *L.O.B.*, vol. 14, p. 154, 1930.
[2]Plaskett and Pearce, *Pub.D.A.O.*, vol. 5, p. 197, 1935.
[3]Joy, *Ap.J.*, vol. 89, p. 356, 1939.
[4]Wilson, *Ap.J.*, vol. 92, p. 179, 1940.
[5]Shapley, *Proc.Nat.Acad.Sci.*, vol. 19, p. 389, 1933.
[6]Hubble, *Ap.J.*, vol. 79, p. 8, 1934.
[7]van de Kamp, *A.J.*, vol. 42, 97, 1932.
[8]Stebbins and Whitford, *Ap.J.*, vol. 84, p. 132, 1936.
[9]Russell, *Proc.Nat.Acad.Sci.*, vol 8. p. 115, 1922.
[10]Struve, Keenan and Hynek, *Ap.J.*, vol. 79, p. 1, 1934; Rudnik, *Ap.J.*, vol. 83, p. 394, 1936; Greenstein, *Ap.J.*, vol. 87, p. 151, 1938.
[11]Struve, *Jour.Wash.Acad.Sci.*, vol. 31, p. 217, 1941.
[12]Huggins, *Phil.Trans.Roy.Soc.*, 1864; Secchi, *Comptes Rendus*, vol. 60, p. 543, 1865.
[13]Hartmann, *Ap.J.*, vol. 19, p. 268, 1904; Heger, *L.O.B.*, vol. 10, p. 141, 1919; Dunham and Adams, *A.A.S.*, vol. 39, p. 5, 1937;* Dunham, *P.A.S.P.*, vol. 40, p. 26, 1937; Dunham and Adams, *P.A.S.P.*, vol. 53, p. 341, 1941.
[14]Struve, *Jour.Wash.Acad.Sci.*, vol. 31, p. 217, 1941.
[15]McKellar, *P.A.S.P.*, vol. 52, p. 307, 1940, *Pub. D.A.O.*, vol. 7, p. 251, 1941.
[16]Adams, *Ap.J.*, vol. 93, p. 11, 1941.
[17]Douglas and Herzberg, *Ap.J.*, vol. 94, p. 381, 1941.
[18]Beals, *M. N.*, vol. 96, p. 661, 1936.
[19]Beals, *A.A.S.*, vol. 9, p. 115, 1937; *Ap.J.*, vol. 87, p. 568, 1938.
[20]Adams, *Ap.J.*, vol. 97, p. 105, 1942.
[21]Merrill and Wilson, *Ap.J.*, vol. 87, p. 9, 1938.
[22]Oort, *B.A.N.*, vol. 6, p. 249, 1936; *Ann.d'Ap.*, vol. 1, p. 71, 1938.
[23]Greenstein, *H.C.*, No. 422, 1937.
[24]Dunham, *Proc.Am.Phil.Soc.*, vol. 81, p. 277, 1939.
[25]Struve, *Proc.Nat.Acad.Sci.*, vol. 25, p. 36, 1939.

ECLIPSE PREDICTIONS

By J. W. Campbell and H. E. Johns

I. Introduction

GENERAL data concerning the eclipses that are to occur each year are given in the Nautical Almanac, and by using the tables of Besselian numbers which are there given one can find the circumstances of an eclipse for any locality. The Besselian method is rather long and tedious, and when accuracy of a high order is desired its use is essential, but for some results a certain graphical method given by Professor N. F. Dupuis* is sufficient.

Dupuis' method is not brief, but the procedure is easy to visualize and for instructional purposes it has some advantages. The terminology and technique given do not correspond to present day practice, however, and it is the purpose of this article to present the method in a form more convenient for use on present day standards.

II. The Principle Used

During the interval while an eclipse is occurring the positions of the sun and moon are confined to a small region of the sky, so small that if the spherical lines of right ascension and declination for the region are plotted on a sheet of paper they will appear essentially as straight lines and give an orthogonal mesh. Then if one calculates the positions of the sun and moon, as seen from the place of observation at intervals of an hour for four or five hours covering the eclipse, he may place the centre of the sun at a convenient point on an ordinary sheet of graph paper and plot the relative positions of the centre of the moon at the times of calculation.

The positions of the moon will determine a locus, which will probably be curved but approximately a straight line. This locus will represent the path of the moon relative to the sun, over the interval concerned. As one looks at the sky and holds his graph sheet over the place where the eclipse will occur, with vertical lines of the sheet parallel to the hour circles of the sky, the right ascension coordinates in the sky increase from right to left. The right ascension number scale on the sheet should therefore increase from right

*Transactions of the Royal Society of Canada, Section III, 1889, pp. 57-64.

to left. Then, by the locus obtained on the sheet it will always turn out that the moon moves from right to left relative to the sun.

Now if one draws a circle about the centre of the sun with radius equal to the angular semi-diameter of the sun, and another circle with centre on the moon's locus and radius equal to the semi-diameter of the moon he can get various aspects of the eclipse from different positions of the moon's centre. Thus, when the circles first touch there would be first contact and when they last touch there would be last contact, and the positions of the centres at these times would give the times of beginning and ending of the eclipse.

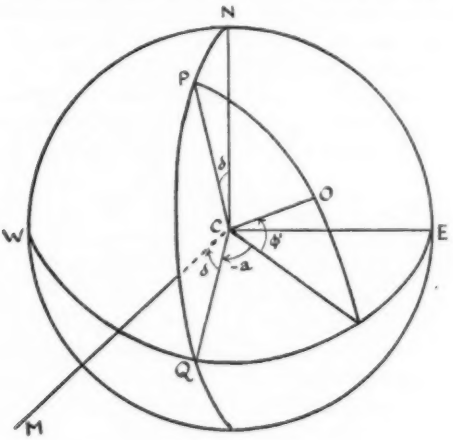


Fig. 1

Of course, in all of this, suitable allowance must be made for the fact that the hour circles of the region of the eclipse are "crowded together" if the declination is not zero. This will be accomplished if differences in right ascension are multiplied by the cosine of the declination when plotting on the graph sheet.

III. Parallactic Corrections

The positions of the moon given in the Nautical Almanac are the positions of the centre of the moon as they would be seen from the centre of the earth, whereas for eclipse purposes one wants the posi-

tions as seen from the place of observation in question on the earth's surface. Now the parallactic displacement of the moon as seen from any point on the earth's surface is equal in magnitude, but opposite in direction, to the angular displacement of the point on the earth's surface relative to the earth's centre and as seen from the moon's centre.

In figure 1 the sphere represents the earth as seen from the moon, M; P is the north pole of the earth, WQE is the equator, O is the "place" on the earth, and ECN is the plane through the centre of the earth and normal to MC; ϕ' is the geocentric latitude of O, and δ and a are the declination and hour angle (east) of M.

Then with reference to the axes $C.EPQ$ we have the direction cosines

of CO : $(-\sin a \cos \phi', \sin \phi', \cos a \cos \phi')$
of CE : $(1, 0, 0)$
of CN : $(0, \cos \delta, -\sin \delta)$.

Therefore

(i) $\cos < OCN = \sin \phi' \cos \delta - \cos a \cos \phi' \sin \delta$,
$\cos < OCE = -\sin a \cos \phi'$.

Hence if π = the moon's horizontal parallax, as seen from the moon the point O is displaced (relative to the earth's centre) approximately thus:

(ii) to the north by $\pi(\sin \phi' \cos \delta - \cos a \cos \phi' \sin \delta)$,
to the east by $-\pi \sin a \cos \phi'$.

Then if, as seen from O, D is the moon's parallactic displacement north and Δ its parallactic displacement east, it follows that

(iii) $D = \pi(\cos a \cos \phi' \sin \delta - \sin \phi' \cos \delta)$.
$\Delta = \pi \sin a \cos \phi'$.

It is to be noted that these are great circle displacements on a small region of the celestial sphere, and that Δ is not displacement in right ascension.

IV. The Order of Accuracy of (iii)

The values of D and Δ given by (iii) differ from their true values chiefly because they are obtained from orthogonal projections. The reason for this is seen by figure 2.

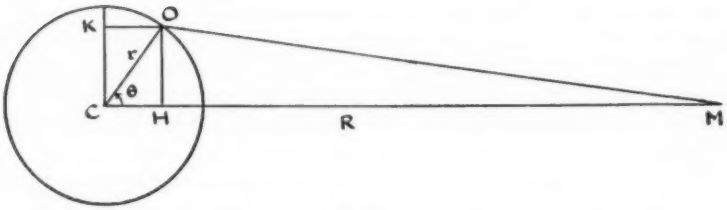


Fig. 2

Here a section of the earth through M and O is shown. By orthogonal projection the measure of the parallactic displacement is taken as

$$\frac{CK}{MC} = \frac{r \sin \theta}{R},$$

whereas it ought to be taken as

$$\frac{HO}{MH} = \frac{r \sin \theta}{R - r \cos \theta}.$$

The error in measure is therefore

$$\frac{r \sin \theta}{R - r \cos \theta} - \frac{r \sin \theta}{R}$$

$$= \pi \sin \theta \left\{ \frac{1}{1 - \pi \cos \theta} 1 - \right\}, \left(\pi = \frac{r}{R} \right)$$

$$= \frac{\pi^2 \sin \theta \cos \theta}{1 - \pi \cos \theta}.$$

The value of π is about $57'$ or $1/60$ radian, and it follows that the maximum value of this expression is about $0'.6$. The displacements D and Δ are components of a total displacement and in general they give values correct to less than $0'.5$.

V. The Technique of a Solution

We adopt the following notation:

α_m = right ascension of the moon,
δ_m = declination of the moon,
a = hour angle of the moon (east),

α_s = right ascension of the (true) sun,
δ_s = declination of the sun,
$\alpha_\odot$ = right ascension of the mean sun,
ϕ = geographical latitude of the place,
ϕ' = geocentric latitude of the place,
$L.T.$ = local time at the place,
π = moon's horizontal parallax,
(x, y) = the position of the centre of the moon east and north, from the centre of the sun, as given on great circles on the celestial sphere at the position of the eclipse.

Thus

(iv) $a = \alpha_m - \alpha_\odot - L.T.$ from noon preceding.

Hence at each instant during the time of eclipse, and for a short period before and after, we have

(v) $x = (\alpha_m - \alpha_\odot) \cos \delta_m + \Delta,$
$y = \delta_m - \delta_s + D.$

By means of a tabular form one calculates at four integral hours of Greenwich Civil Time, which according to the Nautical Almanac cover the complete eclipse time, the values of x and y in minutes of arc.

One then proceeds as explained in Section II.

VI. An Illustration

Calculations on the solar eclipse of July 9, 1945, for Edmonton, latitude 53° 32′ and longitude 113° 30′ W.

*In forming this Table the following points are worth observing:

1. The contour lines of the eclipse maps of the Nautical Almanac indicate the hours for which the calculations should be made. However, it is worth while to leave a blank column at each side of the page so that an extra computation may be conveniently made on either side if necessary, so as to bracket the whole eclipse phenomenon.

2. Slide rule accuracy is sufficient for the computations.

3. The $\alpha_\odot$ is found to the nearest $0^m.1$, and this is sufficient, whereas α_m and α_s are found to the nearest $0^m.01$ and this is necessary. For $\alpha_m - \alpha_\odot$ is used only to find cos a and sin a, whereas $\alpha_m - \alpha_s$ is itself used.

TABLE I*

$\phi' = 53° 21'$, $\cos\phi' = 0.597$. $\sin\phi' = 0.802$,
$\pi = 58'.2$, $\pi\cos\phi' = 34'.7 \equiv A$, $\pi\sin\phi' = 46'.6 \equiv B$.
$D = A\sin\delta_m\cos a - B\cos\delta_m$, $\Delta = A\sin a$.

(1) G.C.T.	11^h0^m	12^h0^m	13^h0^m	14^h0^m
(2) Ed. War. T.	5^h0^m	6^h0^m	7^h0^m	8^h0^m
(3) Ed. L. T.	3^h26^m	4^h26^m	5^h26^m	6^h26^m
(4) δ_m	$23° 7'.4$	$23° 6'.5$	$25° 5'.4$	$23° 4'.2$
(5) δ_s	$22° 22'.9$	$22° 22'.7$	$22° 22'.4$	$22° 22'.1$
(6) a	$7^h8^m.1$	$7^h8^m.2$	$7^h8^m.4$	$7^h8^m.6$
(7) a_m	$7^h7^m.47$	$7^h9^m.96$	$7^h12^m.45$	$7^h14^m.94$
(8) a_s	$7^h13^m.08$	$7^h13^m.25$	$7^h13^m.42$	$7^h13^m.59$
(9) $a_m - a$	$- 0^m.6$	$+ 1^m.7$	$+ 4^m.1$	$+ 6^m.3$
(10) a	$- 15^h26^m.6$	$- 16^h24^m.3$	$- 17^h21^m.9$	$- 18^h19^m.6$
	$+ 8^h33^m.4$	$+ 7^h35^m.7$	$+ 6^h38^m.1$	$+ 5^h40^m.4$
(11) $\cos a$	$- 0.621$	$- 0.406$	$- 0.165$	$+ 0.086$
(12) $\sin a$	$+ 0.784$	$+ 0.914$	$+ 0.986$	$+ 0.996$
(13) $\cos\delta_m$	$+ 0.920$	$+ 0.920$	$+ 0.920$	$+ 0.920$
(14) $\sin\delta_m$	$+ 0.393$	$+ 0.393$	$+ 0.392$	$+ 0.392$
(15) $A\sin\delta_m$	0.1362	0.1362	0.1359	0.1359
(16) $A\sin\delta_m\cos a$	$- 8'.47$	$- 5'.54$	$- 2'.25$	$+ 1'.17$
(17) $B\cos\delta_m$	$+ 42'.8$	$+ 42'.8$	$+ 42'.8$	$+ 42'.8$
(18) $= (16) - (17) = D$	$- 51'.3$	$- 48'.3$	$- 45'.1$	$- 41'.6$
(19) $\delta_m - \delta_s$	$+ 44'.5$	$+ 43'.8$	$+ 43'.0$	$+ 42'.1$
(20) $= (18) + (19) = y$	$- 6'.8$	$- 4'.5$	$- 2'.1$	$+ 0'.5$
(21) $a_m - a_s$	$- 5^m.61$	$- 3^m.29$	$- 0^m.97$	$+ 1^m.35$
(22) $= (21)\times\cos\delta_m$	$- 77'.5$	$- 45'.5$	$- 13'.4$	$+ 18'.7$
(23) $A\sin a = \Delta$	$+ 27'.2$	$+ 31'.7$	$+ 34'.2$	$+ 34'.6$
(24) $= (22) + (23) = x$	$- 50'.3$	$- 13'.8$	$+ 20'.8$	$+ 53'.3$

4. If trigometric tables for angles in hours and minutes are available the entry of (10) as given is sufficient. Otherwise the measures of a can be written in degrees and minutes in the next line.

5. For this eclipse δ_m changed only very slowly so that $\cos\delta_m$ and $\sin\delta_m$ could have been considered constant, but for generality they were considered as variable.

The graph of y against x is shown in figure 3. A circle with centre at O and radius $31'.6$ cuts the graph at t_1 and t_3, and these are the times of beginning and ending of the eclipse. The perpendicular from O to the path gives the point t_2, the time of the middle of the eclipse.

The circles drawn show the sun, and the moon at times t_1, t_2, t_3. From the figure of the sun and of the moon at time t_2 one obtains the percentage of eclipse, i.e. the percentage of diameter eclipsed at maximum eclipse.

The values of t_1, t_2, and t_3 are obtained by interpolation, and the percentage by calculation, from measurements on the figure.

In Table II the results obtained are given, and for comparison the values derived from the Supplement on the eclipse are also given.

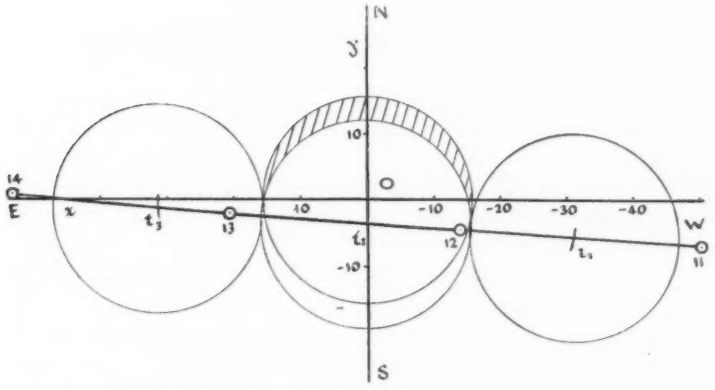


Fig. 3

Path of Moon relative to Sun across the Sky Positions in Minutes of Arc.

TABLE II

	Graph	Supplement
Eclipse begins at	$11^h 31^m.6$	$11^h 31^m.3$
Mid-eclipse at	12 24.3	not given
Eclipse ends at	13 19.6	13 19.9
Percentage of eclipse	88%	89%

VII. Comparison with Correct Values

If one uses the exact formulae of spherical trigonometry then it can be shown that the exact equations determining the value of Δ and D, as defined, are

$$\tan\left(\frac{\Delta}{\cos\delta}\right) = \frac{\pi\cos\phi'\sin a}{\cos\delta - \pi\cos\phi'\cos a},$$

(vi)
$$\sin(\delta + D) = \frac{\sin\delta - \pi\sin\phi'}{\sqrt{1 + \pi^2 - 2(\cos\phi'\cos a\cos\delta + \sin\phi'\cos\delta)}}$$

where π is here the ratio of the radius of the earth at the place of observation to the distance between the centres of the earth and moon.

When Δ and D are calculated by these formulae, there result the following values of x and y:

G.C.T.	11^h	12^h	13^h	14^h
x	$-50'.38$	$-13'.81$	$+20'.76$	$+53'.16$
y	$-6'.85$	$-4'.66$	$-2'.23$	$+0'.18$

A comparison of these values with those given in Table I from the approximate formulae (iii) confirms the inference, as to the order of accuracy, which was made in § IV.

VIII. Remarks

1. For high accuracy the sun's parallactic displacement must be allowed for, whereas the corrections which have been considered here are for the moon alone. But the displacement of the sun is small and is well within the error involved in using Δ and D, as determined by (iii), for the moon.

2. The regular eclipse maps given in the Nautical Almanac are not of sufficiently large scale to enable one to read times of the beginning and ending for places in general to the nearest minute. It is only when a special eclipse Supplement is issued, as was done for the recent July 9 eclipse, that the times for all places can be read to this accuracy.

3. The time scale on the moon's path of the graph sheet is non-uniform. There are several ways in which non-uniformity can be allowed for in making interpolations, but as a matter of fact they do not give appreciable corrections to the results obtained by linear interpolation from figure 3.

University of Alberta
August, 1945.

HER MAJESTY'S MAGNETICAL AND METEOROLOGICAL OBSERVATORY, TORONTO

By A. D. Thiessen

(*Continued from page 319, this volume*)

LEFROY'S tour of the Canadian Northwest was described in Part V of this history.[90]— The financial difficulties that developed later were also mentioned in that part of this narrative. Settlement was eventually made, but not until hard feeling had developed between Lefroy and Sabine over it.[91]

[Editorial Note.—Footnotes 86-89 printed below relate to pages 315-16 of the October issue.]

[86]

Magnetic Observatory,
Toronto, 26 Nov. 1846.

Sir,

In conformity with the directions of the Officer Commanding the Royal Artillery at Kingston, I have the Honor to request that you will be pleased to appoint a Board of Survey consisting of a Captain and two Subalterns, to examine and report upon the Great Coats which have been unserviceable in the Detachments of the Royal Artillery at this Establishment and at the Fort.

I have, etc.
J. H. L.

Lieut. Col. Sir C. Chichester,
etc.
Commanding the Garrison

Magnetic Observatory,
Toronto, 17th December, 1846.

Sir,

Being requested by the Commanding Officer at Kingston to inform him of the number of Artillery Great Coats in your charge after meeting the annual demand, I have the honor to request that you will be pleased to communicate to me a return of the nature required for his information.

I have, etc.,
J. H. L.

W. A. Holwell, Esq.,
D. O. Storekeeper,
Toronto

[87]

Toronto, 14 October, 1848.

Sir,

I have the honor to report to you for the information of the officer commanding, that the Serjeant in charge of the Detachment of the Royal Artillery at the Fort, has represented to me that the state of the Trousers of the men

of his Detachment is such that they are not fit for parade, and cannot be marched to church, and has requested me to authorize him to take the new clothing into wear. Not having any power to do so, I declined giving him such authority, but I intimated to him my opinion that he might himself permit the men to take their new trousers into wear for that purpose only, viz., to enable them to appear properly on Sunday, and told him that I should inform you of my having done so.

I have . . .
J. H. Lefroy, Captain R.A.

Lieut and Adjt N McKay, R.A.,
Kingston.

" Observatory, Toronto, 3 Nov. 1848.

Sir,

With reference to the District Regimental Order of 30th October, I have the honor to transmit the following list of officers, N.C. Officers, and men of my Detachment, who request that copies of the questions and answers on artillery, by Major Burn, may be procured for them.

I have, etc., J. H. L

Lieut. and Adjutant Mackay,
Royal Artillery, etc., Kingston.

List

Battalion.

	Captain Lefroy	1 copy
7	Sergeant James Johnston	1 copy
7	Sergeant James Walker	1 "
2	Bombardier Thos Menzies	1 "
9	Bombardier Chas Jones	1 "
1	Gunner Hugh Jones	1 "

" Magnetic Observatory,
Toronto, Aug. 23, 1850.

Sir,

My attention has been called to the condition and quality of the Barrack bedding issued this day to the Detachment under my command. I found on inspection that the rugs or coverlets are excessively dirty, and with so offensive a smell as to make me suppose that they have been issued by mistake. It appears to me that the blankets are so much worn as to be unfit for the use of the troops. Under these circumstances I have the honor to request that they may be exchanged for other bedding.

I have the honor to be . . .
J. H. Lefroy

The Barrack Master,
etc.; etc., etc., Toronto.

[90]This Journal, 1941, pp. 143-50.

91

Observatory, Toronto,
22nd July, 1847.

My dear Colonel Sabine,

I am glad to learn from your last letter that the Committee of Council of the Royal Society has recommended the claims of the Hudson's Bay Company to the consideration of the Government, and I think I shall meet your wishes by now proceeding to make some comments on the accounts as they were originally made out, in case the particulars should become the subject of discussion. The last time I conversed with Sir George Simpson on the subject, two years ago, I understood that some reduction had been made in the accounts presented about that time to the Treasury, on the sum originally charged for the wages and subsistence of the Voyageurs employed by me: and which was at the rate of 5/s. a day for each man. This would be a very proper reduction; as the expense of feeding them on the produce of their own fisheries during several months of the time, was nearly nominal. As however I have had no particular information on this subject, I must found my remarks on the charges presented to me for signature at Lachine in November, 1844, and of which I was furnished with a copy.

They may be classed under four heads:

1. The first includes canoes and their equipment, the use of Horses and Dogs when travelling by land or ice, Provisions furnished for my own use when actually travelling, winter clothing to the Non-Commissioned Officer; also some articles of that description furnished to myself, and occasional payments to Indians. All imported goods have been charged at 50 per cent. advance on the Invoice price, which is the regular charge in the interior. The whole amounts to £227. 1. 6. and I think is a proper charge.
2. The second comprises incidental expenses, including those incurred in establishing small temporary observatories at Athabaska and McKenzie River, and I think is also a reasonable charge. It amounts to £5. 4. 0.
3. The subsistence of the Non-Commissioned Officer is charged at the uniform rate of 2/6, which must fully cover all the expenses of the Company for him. He was supplied precisely as myself, and the supplies of provisions charged to me, for travelling consumption, are one half of what was actually received for our joint consumption: £70. 10. 0.
4. There is a charge for two Iroquois Buttes, engaged to take me down to Canada, including a sum of £10 each for extra detention, which I know was actually incurred, those men commanding very high wages: £96. 15. 0.

£451. 10. 6.

The whole amounts as above to £451. 10. 6. I do not think that any of these charges can be materially reduced.

There remains the charge made for the men employed by me, usually six in number, sometimes eight, and which is at the rate of 5/s. per day or £91 per annum for each man, although his actual wages which are a principal part of the charge were under £25.

This sum I consider unreasonable. I am aware that it is a rule in the Interior, where Accounts are kept by Districts; to charge at that when the men of one District are employed for the time in another, but this is a fictitious arrangement, and it cannot be pretended that the man's services cost that sum.

The men in my service were never subsisted on a more expensive scale than those employed at the Depots, and as 1/3 a day, exclusive of wages, is what is charged for the subsistence of the two Iroquois who were so long waiting for me at Norway House, I consider that a fair criterion of the expense of their provisions when travelling. If so we may reduce the charge of 5/ a day for wages to half the amount, or 2/6, which I think will cover the *bona fide* expenses.

Under this head then we have £361. 8. 7. instead of £722. 17. 2. and the total charge becomes £812. 19. 1. which amount I consider will be a fair and liberal compensation to the Hudson's Bay Company for all its expense, except those incurred by my subsistence during the winter, and when a guest at any station.

These are not charges, the Company's hospitality having been offered gratuitously to the Officer conducting the Survey.

I have not separated from the first item of £227. 1. 6. the expense of various articles of winter clothing amounting to £10. 2. 6. which were supplied to the N. C. Officer, and were rendered necessary by the peculiarity of his employment. Neither have I separated the items mixed up in various accounts of articles of clothing, and personal expenses chargeable to myself, amounting to £35. 5. 0. The former I think should be borne by the public. The latter can be conveniently charged to me per Treasury Order as a Disallowance by Messrs. Cox and Co. and has only been left unpaid in consequence of the wish expressed by Sir George Simpson, that the whole should stand over together until the final disposal of the claim.

I enclose the abstract of the accounts from whence I have derived the above sums.

Believe me, etc.,
J. H. L.

Lt. Col. Sabine,
Royal Artillery.

July 22, 1847.

ANALYSIS OF THE ACCOUNTS OF THE HUDSON'S BAY COMPANY

1843		£	s.	d.	£	s.	d.
April.	Equipment at Lachine and a share of general expenses of the Brigade	16.	14.	3.			
	Supplies at Fort William, including a new canoe	15.	18.	7.			
	Supplies at Red River	7.	1.	2.			
	" at Norway House	18.	9.	5.			
	" at Oxford House		7.	2.			
	" at York Factory	34.	5.	6.			
	(part to be repaid by Capt. Lefroy)						

	"	at Cumberland House	8. 11.	
	"	at Isle à la Crosse	10. 12. 1.	
1844	"	at Athabaska	22. 5. 3.	
		(part to be repaid by Capt. Lefroy)		
	"	at Dunvegan	2. 10. 0.	
	"	at McKenzie River	29. 11. 11.	
		(part to be repaid by Capt. Lefroy)		
	"	at Edmonton	7. 19. 0.	
	"	at Norway House	14. 4. 5.	
		(part to be repaid by Capt. Lefroy)		
	Expenses of winter journey to McKenzie River		20. 0. 0.	
	Expenses of the return of a party who accompanied from Great Slave Lake		6. 0. 0.	
	Services of Horses from Dunvegan to Edmonton		5. 0. 0.	
	Use of boat and canoe		4. 10. 0.	
	Supplies at Michipicoton		1. 12. 3.	
	Postage p[aid] at the Sault Ste Marie and Lachine		3. 5. 7.	
2.	Incidentals:			
	Indemnity to Guide engaged to take me to Albany, but not emp[loyed]		5. 0. 0.	
	One half of expense of an express canoe sent with letters from Lachine		15. 0. 0.	
	Freight of Box sent to England from Norway Ho[use]		14. 0.	
	Express Canoe with Letters for York Factory		10. 0. 0.	
	Expenses of erection of Observatory at Athabaska		14. 5. 0.	
	Gratuities to Company's servants for extra wood		10. 0. 0.	
	Fitting up room for temporary Observatory at McKenzie's River		1. 5. 0.	
	Gratuity to Guide		1. 0. 0.	
				£57. 4. 0.
3.	Subsist[ence] of one N. C. Officer from 1st May 1843, to November, 1844, at 2/6—			£70. 10. 0.
4.	Wages of Battes (Iroquois steersman and Guide, summer of 1844)		53. 15. 0.	
	Extra for detention		20. 0. 0.	
	Rations 1st May to Nov. at 1/3		23. 0. 0.	
				£96. 15. 0.
				£451. 10. 6.

WAGES AND SUBSISTENCE

1843.	2 men 31 days May	15.	10.	0.
	6 men 71 days June 1st to Aug. 10th	106.	10.	0.
	2 men extra 12 days, return from York Factory	6.	0.	0.
	1 man 100 days to replace steersman who fell sick	25.	0.	0.
	6 men 295 days, 11th Aug. '43 to 1st June, 1844	442.	10.	0.
	3 men 13 days extra at McKenzie's River	9.	15.	0.
	2 men 1st June to 4th September, 96 days	48.	0.	0.
	4 men 1st June to 1st November, 153 days	153.	0.	0.
	4 men from 1 Nov. until date of re-entering the Company's Service	15.	10.	0.
	1 man 21 days until his discharge at Montreal	1.	2.	2.
		£722.	17.	2.
	Reduced to one half		£361.	8. 7.
			£812.	19. 1.

Toronto, 23rd July, 1847 (Signed) J. H. Lefroy,
Capt R.A.

Amount to be repaid by Capt. Lefroy ..... £35. 5. 0.

PART XI.—OBSERVATIONS OF AURORA BOREALIS AND THE APPLICATION OF PHOTOGRAPHY IN MAKING MAGNETIC RECORDS.

(November 20, 1846 to November 12, 1850)

DURING this period Lefroy tried to prepare for publication the records of his magnetic survey; he set up photographic equipment in the Toronto Observatory and experienced great difficulty in mastering a new technique; and he instructed the Non-commissioned Officers in the Guard Rooms in Canada in the methods of observing northern lights and recording observations. That there was a connection between northern lights and magnetic disturbances seemed to him obvious, and he wished to establish that fact. The letters of this period show in what manner and direction Lefroy's initiative developed. As letters discussing the arrival and non-arrival of instruments have a direct bearing on the interpretation of the results obtained during these early difficult years, they are published in this series.

The first letter mentions instruments.

Magnetical Observatory,
Toronto, 19th July, 1847.

Sir,

I have the honor to request that you will cause inquiry to be made for a certain deal case, length about 12 feet, other dimensions small, containing instruments for this Establishment, which was shipped on Board the *Apollo* troop ship, with two other cases, in charge of Gunner Jones, Royal Artillery, and which it appears was left on board at Quebec; the others having been brought on by him. These cases are addressed

H. M. Service
The Magnetic Observatory
Toronto, Canada
per *Apollo*

and are shipped by authority from the Board of Ordnance.

I have to request the shipping case may be forwarded by the earliest opportunity.

I have, etc.

R. Penn, Esq., J. H. L.
Ordnance Storekeeper, etc.,
Quebec.

The purpose of the observations of the aurora is clearly set out in the next letter, and the "Instructions" accompanying it.

Observatory, Toronto,
3rd December, 1847.

My dear Sir,

I have the sanction of Colonel Dynelly to an application which I beg to make to you, for permission to place a book in the Barrack Guard room at Quebec, to contain a record of every instance of Aurora which falls under the observation of the N.C. Officers conducting reliefs, to be in charge of the Serjt. of the Guard and copied on loose sheets which may be sent off by post or otherwise to me as fast as they are filled. I shall feel much obliged to you if you will favour me with your assistance and authority in making this arrangement effective.

The direct object is to obtain a record of every appearance of aurora in Canada and to ascertain whether it has been seen at a distance upon occasions when the state of the sky may have prevented us from seeing it here. I need not tell you that there is a connexion between displays of aurora and what are called magnetic disturbances, or occasions on which the variation and the force of the Earth's magnetism undergo great and irregular changes. At present scarcely anything is known of the nature of this connexion, but it is desirable to know whether great disturbances, which can only be discovered by the instruments of an observatory, ever occur without aurora being seen somewhere, or on the other hand, whether any considerable display of aurora can take place, anywhere, without the occurrence of a disturbance. This can only be done by a comparison of registers kept in places at some distance from one another, and I

have permission from Col. Dynelly to place a book for the purpose in each of our Regimental Guard Rooms. There are other objects which may be answered by such a register, if intelligently and carefully kept, but as I can neither expect nor desire N.C. Officers on guard to devote themselves particularly to anything of this kind, I limited my wishes to that which may be done at very little cost of time and trouble. The book for Quebec is ready, and contains short instructions. I shall also send with it some ruled paper for the copy which I should wish kept up, and dispatched as the sheets are filled to insure our getting the information we want while the interest is recent.

I should be glad if the Thermometer could be recorded at least 4 times a day, but I do not know how far this may be convenient. It is not indeed of much importance, as the temperature of Quebec is pretty well known, but it would sometimes be inter.sting for comparison.

The aurora has been very frequent everywhere this year. On the 24th October last brilliant displays took place all over Europe as far as Madrid. On the same day we had a great disturbance of the magnet here, but the night was thickly clouded and no aurora could be seen. In such a case as this the record of such a thing having been seen at Quebec or elsewhere would have been very interesting.

Believe me, My dear Sir,

Lieut. Col. T. Gordon Higgins,
Royal Artillery, Quebec.

Yours very faithfully J. H. Lefroy.

Letters of the same date and purport were addressed to Commanding Officers of Artillery at Kingston, London, and Montreal.

A copy of the Instructions for observing the Aurora is appended hereto.

INSTRUCTIONS FOR N. C. OFFICERS CONDUCTING RELIEFS

N. C. Officers conducting reliefs are requested to take notice of any appearance of Aurora that may present itself during the nights, and to make an entry of the occurrence in this Book.

Auroras may be divided into four classes:

1. A faint light in the north, without s nsible form or boundary.
2. Arches resembling rainbows in size and form, but of an uniform white colour, and sometimes retaining their apparent position for a considerable time without change. They vary in brightness and in the apparent density of their light. It should be particularly noted where they have a streaked appearance, like wool or cotton which has been carded out. This appearance is described by the term 'Striated.' It will be convenient to employ a scale of terms to denote the degree of brightness thus— Faint — Moderate — Bright — Very bright.
3. Detached floating patches of light, resembling light clouds.

4. Streamers, Waves, and Serpentine bands, which are in more or less active motion, and change their place and form with rapidity. These form the brightest and finest displays.

It is desirable that some general description should be given to shew to which class each aurora belongs. and when it passes from one to another. State also, if possible, the following particulars:—The hour when first noticed, the time when it was brightest, the time when it passed to the south of the zenith (or part of the heavens immediately overhead) and the hour when it disappeared. The height of arches above the horizon, by estimation or by measurement, and the position of the two ends, which can be given within a point or two by facing the Pole Star, and noticing whether a half or quarter, or three-quarter turn brings the end of the Arch directly in front. The more precise the description the better, and if a N. C. Officer has a watch, and knows how much it is fast or slow he should state within a minute or two, the time of any appearance or any position he records.

These particulars should be noted on a slate or otherwise at the time, and written out at leisure before the guard is relieved.

The height of Arches above the horizon is best measured by a simple wooden quadrant and plummet, which may be made out of any straight-edged piece of board, by marking a quarter circle at the end, and suspending a small plummet from the centre. The quarter circle should be divided into nine parts each of 10°, and each of these subdivided into two, each of 5°, or it may be more carefully divided into the 90 degrees

The simple record of the fact of an Aurora having been seen (without any of these particulars) will have small value, the object of this record being in a great measure to ascertain when Aurora existed and has been visible at a distance from Toronto, without having been seen there, but the more particulars are given the greater the probability of their being of some further use.

The Serjeant of the Guard will make an entry in the book, whether there has been any Aurora or not, affixing his initials.

The following may be taken as examples.

Wednesday, Dec. 23.	Night fair, no wind, unclouded until daylight.
Thursday. Dec. 24.	An arch was seen in the north 10 m. past 8 about 10° above the horizon, extended from NW to NNE. Moderately bright. At 10 the sky covered with Aurora very bright, faint tinge of red—both N and S of the zenith. Streamers darting from E to W. At 12 no more Aurora except a faint light in the north, light wind from NW.
Sunday, Dec. 26.	Partly clouded, not more than 2/10 sky cleared at any time.
Monday, Dec. 27.	Show from 2 to 5 am.; calm, clear all night. At 12 arch about 30° above horizon from NW to NE. Faint. Gunner AB reports that it began to rise soon after he mounted sentry, and broke up into bright waves and

Tuesday, Dec. 28.	streamers about ¼ before 1. No Aurora at 2. Violent easterly gale with snow all day. At noon about E, at 2 about E, at 4 SE, at 6 SE, at 8 nearly west. Ceased snowing at 7, wind hardest about half past 3 from SE, it went after 8 pm.
Wednesday, Dec. 29.	Cloudy night, but there is an appearance of light through breaks in the clouds at 10 and 12 as if there was Aurora behind them; wind fresh from NE.
Thursday, Dec. 30.	Cloudy night, calm, rain at intervals.

The above are instances of the different observations that may be made; N.C. Officers may extend them or notice anything else that seems worth recording, at their own discretion. It will not be necessary to give more than a general statement of the prevailing wind, except in the case of great storms, when the wind should be recorded at every relief, and the time of a sudden change be particularly noted.

The following is the scale of terms for the wind usually employed:

Number	Terms
0.	Calm
1.	light air
2.	light breeze
3.	gentle breeze
4.	moderate breeze
5.	fresh breeze
6.	strong breeze
7.	moderate gale
8.	fresh gale
9.	strong gale
10.	whole gale

These terms should be adhered to.

If a thermometer is at hand it should be registered at 6 and 8 in the morning and 2 and 4 in the afternoon, or oftener in very changeable weather. The hours adopted should be adhered to regularly.

J. H. L.

The great astronomer Sir John Herschel was greatly interested in these observations of the northern lights and praised the work that was being done by the Royal Artillery in Canada, at Lefroy's instigation.

Toronto, Canada,
19th May, 1848.

Dear Sir,

At the commencement of last winter I obtained Col. Dynelly's permission to place a Book in each of four Regimental Guard Rooms in Canada, to receive a short daily record of the weather, and more particularly of all appearances of Aurora which fell under the observation of the N.C. Officers conducting reliefs, having found these records interesting and likely to be valuable, I am encouraged

to beg the favor of your assistance in extending the system to Newfoundland. I need scarcely say that as any thing of this kind is foreign to the immediate duties of the N. C. Officers on Guard, it is not intended to be made a burden, or to be carried into details which might direct their attention from more important duties,—I wish the fact of every aurora to be registered, and a few of the leading particulars noted, but do not at all desire elaborate accounts. The register is made daily chiefly for the sake of keeping up the habit. It does however sometimes happen that other matters of interest beside auroras present themselves, which might not otherwise be noted. I have no doubt that if these registers can be kept up for a year or two, they will lead to valuable information about the aurora itself, which is very little understood, but my more immediate object in making the request with which I now trouble you, is to obtain information likely to throw light upon the connection supposed to exist between the Aurora and particular states of the earth's magnetism, which latter are the subjects of the observations made here. The registers are at present kept at Quebec, Montreal, Kingston, Toronto, and London, C.W., to which I hope to be able to add Fredericton and Halifax. In the hope that you may be able to meet my wishes, and may see nothing objectionable in this mode of occupying the attention of the N.C. Officers on Guard, I beg leave to transmit herewith a book similar to those I have sent to the Stations in this country, and containing the same instructions. I don't know what the post-office arrangements at Newfoundland are, perhaps you may be able to send the separate sheets as they are copied, to Quebec, during part of the year, but if not, I would beg the favour that they may be sent under cover, on H.M.S. to Col. Sabine, 'Superintendent Magnetical Observatories', Woolwich. He will forward them to me, or they may be kept for private opportunities of transmission either to Woolwich or to Canada, as it is no great object to receive them at once. Perhaps I cannot give to those brother officers who may kindly take the trouble of seeing these registers kept, a better proof that their trouble will not be thrown away, than by copying a passage in a letter from Sir John Herschel to Colonel Sabine who favored me with a copy of it. "I have read with a great deal of interest as well as instruction, the journal of the appearances and nonappearances of the Aurora Borealis, kept in the Guard Rooms at Kingston and Quebec by the N.C. Officers on duty. The way in which the entries, are made, and the clear and intelligible way in which the appearances are described are not only very creditable to the parties making them. but very interesting in themselves when compared *inter se* and with the magnetic observations made in the Observatory of Toronto." He adds "assuredly in a country where these phenomena are so frequent, no means should be neglected to extend the base of observations over a wide tract of country, and if, as it would seem from these specimens such efficient observations can be obtained from the spread of intelligent interest among the N. C. Officers at Government posts, I think they ought by all means to be encouraged to make them." (Collingwood, 28 April.) The great weight which belongs to an opinion of Sir John Herschel, will make it, I am sure, needless for me to say more to engage an interest in the matter.

Believe me, my dear Sir, Yours very faithfully,

J. H. Lefroy.

We have already discovered that Lefroy was willing to work day and night when necessary. He wrote an interesting letter on one of these night watches, January 1st, 1849.

Toronto,
1 January, 1849.

My dear Colonel

I think I cannot do better than appropriate a part of my first night watch (except in the North-west) for seven years to the pleasure of offering you all the good wishes connected with the return of this day. I was truly sorry to learn by Younghusband's last letter that you have had a serious and painful attack of rheumatic fever, I believe one of the most painful complaints that are known, and I heartily hope that the expectation he expresses has been realized, by your recovery from it by this time. If the arguments which I am sure Mrs. Sabine and Mrs. Lewes must urge for your sparing yourself, are ineffectual, I can expect no effect from mine, but I must say, that I wonder more at your general health, under the circumstances of such an incessant and long continued application of the mind, than at an occasional failure in it. I will only add that my best services are at your command to relieve you of any portion of your labour, whether in connection with the observations at Toronto, or any other station, that my strength may be equal to, and that I always shall feel that the helping forward the objects in which we have been now associated for ten years, has a prior claim to any thing else on all of us, so long as any part of the work of publication remains to do. With regard to my remark about night watches, I have returned to hourly observations, as the only way of carrying out completely the objects to which our last year is to be devoted. We might have waited until the arrival of the photographic instruments, but it would have been unsatisfactory to have broken a portion of a year on this principle. I decided therefore on anticipating them. My principal object is to insure the observation of every aurora, which could be done in no other way, but it is also desirable for a comparison of movements of disturbances when they occur. The loss of Serjeant Johnston, and the clumsiness of the man they have given me instead makes it necessary for me to take a tour of the night duty as I always did at St. Helena, but never before here. I have made some other trifling changes with a view to economy in labour. One is discontinuing registers by Osler's anemometer, except during gales of wind, and relying altogether on Robinson's, but in most respects we shall go on just as of old, keeping up the term days, absolute determinations, and abstracts of everything. We have not heard a word from the Ordnance, or drawn sixpence of contingent money or working pay, since *last March*. With kind regards and best wishes of the season to Mrs Sabine, believe me, very faithfully yours

J. H. Lefroy.

The Americans were interested in the observation of northern lights at this time, also.

Observatory, Toronto,
12 January, 1849.

Sir,

I took the liberty of opening your letter addressed to Lieut. Col. Sabine, Toronto, conceiving it almost impossible that it could be private, as Col. Sabine has never resided in Toronto, and rather apprehending it to be a communication intended for the officer directing the magnetic observatory. Perceiving the nature of its contents, I have forwarded it to Colonel Sabine.

Permit me to take advantage of this accident by forwarding to you a paper relating to observations on Aurora, which I am anxious to extend and to solicit the favor of notices from Ipswich, if convenient. The paper was, as will be evident, prepared for intelligent but unscientific observers, and will itself be of no further use, than as shewing what is desired, and tending to uniformity of system. I hesitate to send one of the maps of the stars alluded to, on the score of postage, but shall be happy to do so if agreeable, or to communicate any further explanation or information in my paper.

I have the honor, etc., J. H. L.

I. M. Batchelder, Esq.,
Ipswich, Mass.

In a remarkable passage in one of his letters Lefroy believes to see a connection between disease and terrestrial magnetism, for he says:

"It would appear as if at the present moment, while Cholera is prevalent in Toronto, the ordinary electro-magnetic influences are inoperative . . . I do not like to speak positively. We feel now the want of any apparatus for atmospheric electricity."

Observatory,
Toronto, Aug. 15, 1849.

My dear Colonel,

I am very glad to find that the monthly series of Absolute Horizontal Force determinations is beginning to have the value which I always believed it would have. I inclose the last six months of 1849 and a copy of January 1847, which Younghusband has requested, but must beg a little time for the observations of this year, none of which are made up. It will take about a fortnight to get them ready. As our continuance here was quite uncertain, we discontinued forming abstracts of the magnetical observations in February, when the several series came to an end, and new series began with all the instruments except the small

Bifilar. The meteorological observations have been abstracted, as they were required for other purposes, and as I was anxious to complete, at all event, as ten years series with them, I might have had the Bifilar observations reduced as usual, but, as I have frequently mentioned, every thing involving the application of the bifilar coefficient has been at a standstill, until it is settled what values we are to use. This question has now been awaiting your decision six or eight months, to my great obstruction in many ways, for it must be evident that I cannot enter into any extensive investigation or correction involving the use of the coefficient, so long as I am liable to have my own decision on the point overruled at Woolwich. I am quite ready to decide the question myself or rather I have done so long ago, and have stated my grounds for so doing, but wholly without responsibility as I feel myself in the final preparation of the work for publication, and in ignorance as I am of your proceedings, you cannot be surprised, that I suspend all action on my own judgment, or *as much as I can*, while there is no security that my work will not have to be done over again. Together with the bifilar returns, all enquiries as to changes of Dip and Total Force, which involve that coefficient have been discarded. And all our disturbances and observations kept in an incomplete state as regards those elements. The consequence is a great accumulation of arrears.

We have several independent series from which the annual and secular change may be deduced. I inclose copies of the Daily determinations of the Absolute H.F. by the vibrations of bar **17**, which gives both for three years, exclusive of the current year. The monthly or fortnightly values give a very regular annual curve and they shew a decided decrease in the mean value. There are again the Absolute determinations with the survey magnets. With regard to the annual curve, the fortnightly means by the large Bifilar, as given on the accompanying sheet marked *A*, although irregular, give its law clearly enough. A maximum in July, another in December, a minimum in March or April, another in October or November. This is best shewn by laying them down and sweeping a mean curve through the irregularities. It is curious that the maxima are not equidistant: from the winter one to the summer one is much further than from the summer one to the winter one succeeding.

You request the Absolute Determinations reduced to the monthly mean bifilar scale reading. In order to have the series as independent as possible of the Bifilar, I adopted the plan of reducing the observations to the mean scale reading of the day in which they were made so as to eliminate changes of Force between the several parts of the observations, but nothing more. These scale readings, and the monthly means also, are stated on each return, and as the reduction from one to the other can easily be made in your office, I don't delay them to perform it.

I transmit a memoir of all the adjustments of the small Bifilar, having already done so for the large one and the Declinometer. The new abstract of the large Bifilar was made provisionally, to see whether our new values give a closer agreement between the curves than we had from the original values, if you do not concur with me as to the coefficient employed, it will go for nothing. I think

myself there is a specific difference between the diurnal curves given by large and small instruments, and Lloyd seemed to admit as much, when he examined a few months I sent him as an example, a long time ago. This would be a very curious circumstance to establish.

I have left my letter to Borrow open, and shall be obliged if you will read it, to understand the state of the actinometer he sent out last.

The photographic observations have been at a standstill for nearly a month, owing to a very curious difficulty we have met with in remagnetizing the bar. I shall write about it at length by-and-bye [*sic*]. It would appear as if at the present moment, while cholera is prevalent in Toronto, the oridinary electro-magnetic influences are inoperative. I have made many experiments with Crofts and Hinds, (Lecturer at the Normal School) and we shall perhaps be able to make something out of the matter, but as there is a great liability to mistake in experiments of this nature, I do not like to speak positively. We feel now the want of any apparatus for atmospheric electricity.

Believe me, Yours very truly,
J. H. Lefroy

More instruments arrived in April, 1850.[92]

[92]

Magnetic Observatory,
Toronto, 27th April, 1850.

Gentlemen,

I beg to inclose the invoice of three cases shipped to my address on board the *Lady Elgin*. It is of great importance that they be forwarded with the utmost care, and not in any way examined or opened at Montreal, the instruments contained in them being of a nature to be easily injured.

I add the invoice of two cases on board the *Pearl* containing instruments of the same nature. I beg the favour of your particular attention to the unloading and forwarding of these five cases. Their contents are very delicate and valuable. If any further particulars or arrangements are necessary to secure their transmission without loss of time, and without examination at the Custom House, I shall feel obliged by immediate information.

I remain, Gentlemen, Your obedient Servant
J. H. Lefroy

Messrs McPherson Crane and Co.
Montreal

The captains of both vessels are aware of the nature of the contents of these cases, and have been requested to make them the objects of their particular care.

(*To be continued*)

TYCHO'S NOVA, 1572

By Francis P. Morgan

IN the beginning of November 1572 there appeared in the constellation of Cassiopeia a nova the like of which has never been observed since. Of course, there was no equipment in those days, but there were some competent visual observers who kept a record of the light and colour changes, details of which are published in "The Sidereal Heavens" by Thomas Dick, 1866.

During the first three weeks after its discovery by Tycho Brahe it shone with a brilliancy equal to that of Venus at maximum and was seen by many in daylight. By the end of December it had diminished to the magnitude of Jupiter. In January 1573 it was intermediate in brightness between Jupiter and a first magnitude star. In February and March it was of the first magnitude, and in April and May it was of the second. It continued to fade slowly until it disappeared in March 1574, sixteen months after its appearance.

There were also colour changes, which I consider of significance. At maximum it was white. As it faded, it turned yellow, then red and then turned white again. In March 1573 the colour was estimated as being about the same as that of Aldebaran.

It is generally believed to-day that it was a supernova. For reasons to be discussed below, I think it more likely that it was a close common nova. In either case, there is much that can be learned from it. If it was a common nova, it would have been one of the intrinsically fainter types, and so must have been very close to have appeared so bright. In fact, if it could be identified to-day, it would reveal a measurable parallax, and its nearness would probably yield valuable information regarding the nature of novae in general. If it were a supernova, there are interesting conclusions that we could draw from the colour changes.

It is the reddening which occurred on the decline which I think favours the theory that it was a common nova. In some novae the emission lines of hydrogen are so strong that the star appears red as viewed by the naked eye. Thus it deviates considerably from a black body radiator. The best recent example is that of Nova Puppis, 1942, which I observed at maximum as appearing to

the naked eye as red as Antares. Of course, it differed from Tycho's Nova in that it was reddest at maximum, while the latter was reddest during the decline, but this difference could well be associated with the difference in the light curves. Nova Puppis was a rapid nova, while Tycho's Nova, if it was a common nova, was of the slow type.

No hydrogen has been detected in the spectra of supernovae observed in spiral galaxies, although helium and iron are abundant. If it be assumed that the reddening of Tycho's Nova be due to an abundance of hydrogen, it may be inferred that it was a common nova, since hydrogen is so scarce in supernovae. On this assumption, it is possible to determine its distance with fair accuracy.

Recently, McLaughlin found a relationship between the light curves and absolute magnitude of common novae. If $t3$ be considered the time required for a drop of three magnitudes from maximum, then where $M = -8.2$, $t3 = 10$ days. Where $M = -7.2$, $t3 = 30$ days. Where $M = -6.5$, $t3 = 60$ days. Where $M = -5.4$, $t3 = 200$ days. And where $M = -3.6$, $t3 = 1000$ days.

Tycho's Nova at maximum was about $m = -4.2$. The problem is to find at what time m was -1.2. Visual observations were not made with the same accuracy then as to-day, but its brightness in January 1573 is given as intermediate between that of Jupiter and a first magnitude star, which sets it at roughly $-.5$ for the middle of the month. A value of $m = -1.2$ for the beginning of the month, or two months after maximum, is probably not far from right, in which case $t3 = 60$ days. According to the above formula, then $M = -6.5$. Since $m = -4.2$, its distance could not have been more than 30 parsecs, assuming it was a common nova. This is well within the range of modern methods of measuring parallaxes.

On the other hand, we must also consider the possibility that a reddening of the light of supernovae may also arise from causes other than that which produces the effect in common types. Owing to the scarcity of hydrogen, a supernova is more likely to radiate as a black body than a common nova. Therefore, reddening would best be explained by the cooling of a rapidly expanding photosphere of enormous dimensions and of substantial density. If the colour estimates of Tycho's Nova were correct, when it was reddest its

surface temperature would have been about the same as that of Aldebaran, assuming it was a supernova.

Assuming a maximum value of $M = -15$, the average of supernovae, then at its reddest it would have been $M = -10$, since by that time m was $+1$. To emit so much light it would have had a radius of 100 times that of Aldebaran itself, or more than big enough to fill the orbit of Uranus, and yet this great shell of gas would have to be of sufficient density to prevent the bluer rays of the central star from filtering through. This would indicate that supernovae lose a substantial portion of their total mass.

There is a way in which it may be determined to which type the nova belonged. If it were a common nova its identification need not be too difficult. It would be one of the rare types of stars, probably a white subdwarf, with a parallax of the order of ″.03. Its discovery might be accomplished by a study of the proper motions and photographic parallaxes of the stars in the field of the nova. Those stars for which a parallax is obtainable should be selected for study as to colour, and if possible, for spectral type. If a white subdwarf or any other unusual type should be found at a distance of the order of 30 parsecs, it would be safe to assume that this was the nova.

If no unusual types are to be found among those near enough to reveal a detectable parallax, it may be inferred that it was a supernova. In either case, it is unlikely that it would be below the tenth magnitude. It is probable that it is already catalogued, though unidentified.

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THE ECLIPSE OF JULY 9—OBSERVATIONS BY WINNIPEG MEMBERS

By Olive A. Armstrong

Members of the Winnipeg Centre saw the eclipse from several points.

Mr. Norris-Elye journeyed by car to Pine River where the sky was clear, and he succeeded in obtaining a good photograph of the "diamond-ring" effect that was published widely across Canada.

Mr. A. V. Thomas motored to Roblin but was unfortunate in having an overcast sky.

Mr. G. P. Morse went to Winnipegosis where the view was good and he succeeded in taking a really remarkable picture in an ordinary camera (see p. 256).

The largest party went by train to Wolseley. The seven fortunates included Mr. V. C. and Mrs. Jones and daughter Margaret, Miss M. E. Watterson, Miss F. B. Sharman, Mr. L. W. Koser and Miss O. A. Armstrong.

A pleasant feature of the stay in the pretty little town was the afternoon tea given on Sunday by the Mayor, Mr. Stanley Cole, and his wife. While real country food was nibbled, the "great" from Portland, Oregon, to Portland, Maine and far south, and the "not so great" mingled to catch and share the excitement. The hospitality and widespread kindness of everyone in the town was and will be, for a long time to come, commented upon.

Rain in generous supply fell on Sunday morning. This thoroughly washed the air, and perhaps was responsible for the out-of-the-ordinary colour the following morning.

The Winnipeg party arose at 4 A.M. (M.D.T.) and found the sky cloud rimmed but clear overhead with planets and many stars visible. Venus remained visible throughout the time till after the eclipse.

The cold 40° or 39° F., with a strong wind, was bitter. The long grass was dew-soaked and so, soon were the spectators. Food in the shape of sandwiches (alas, no hot coffee!) didn't seem to help much. A small bonfire started to burn lunch papers but added to by many people, helped slightly.

Mist rose off the little dammed stream to the east. Birds twittered, a nesting duck was decidedly uneasy at the unusual noise of many cars and people. Everyone discussed the spreading or dispersal of the narrow cloud-bank. The sun rose clear, became clouded and then cleared again before first contact.

The partial phase seemed to last an eternity. In the darkening light the crescent shadows under the many nearby trees were ethereal. A few seconds before second contact several noted the shadow bands but few agreed as to their direction or size. (Note: *Sky and Telescope*, Sept. 1945.)

Just at the moment before totality a freight train from the east glided silently into the Station, steam shut off, while the train crew took in the celestial spectacle.

Baily's Beads lasted only an instant and then the corona flashed out. No one could have missed noticing the appearance of the "magnetic field." A photograph does poor justice to this or the gauzy termination of the aurora-like streamers.

One prominence was easily seen at the upper left, another smaller one at the lower left, and as the moon moved another appeared at the upper right. Binoculars aided greatly in seeing these but were not a necessity after the eyes became accustomed to the dark. The flame-colour of the prominences, the pearly background of the corona and the slate-colour grey-green of the atmosphere made an impression that can never be forgotten.

The shadow cone's edges were as easily noticed as rain falling from a distant cloud.

Before even half of the usual time of 34 seconds seemed to have elapsed Baily's Beads and a marvellous scintillating diamond ring appeared. It was impossible to believe the corona that was real a few seconds before could not be found!

A rooster crowed. People stirred to get home and warm again. The shadow bands and crescent shadows appeared again. Everyone talked at once and it was not long till the Winnipeggers were having hot coffee and hot food. The location of the 1954 eclipse was one engrossing topic of conversation.

REVIEW OF PUBLICATIONS

Dynamic Meteorology by Jörgen Holmboe, George E. Forsythe and William Gustin. 378 + xvi pages, 5½ × 8½ in. New York, John Wiley and Sons, Inc.; London, Chapman and Hall. 1945. Price $4.50.

The authors state that this book is intended as a basic textbook in theoretical meteorology for students who are preparing for a professional career in meteorology. The non-mathematical reader, therefore, must not expect to browse through it easily.

Despite the relatively difficult nature of the mathematics, the whole work is remarkably self-contained, bearing out the authors' claim that only some general knowledge of physics and calculus is presupposed. For example, the subject of vector analysis, which is used a great deal, is developed "from scratch".

The book starts with the general laws of physics which relate to gases, and gradually and in a very orderly manner shows how these can be applied to the behaviour of the earth's atmosphere. To the non-meteorologist who may still think that the subject is largely governed by empirical laws it may be a revelation to find how far meteorology now lends itself to mathematical treatment.

Two features of this book particularly impressed the reviewer: first, the very valuable index, right at the beginning, of all symbols and constants with their actual values where applicable; second, the stress laid on dimensional analysis as a first check on an equation's correctness.

J. F. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Long Focus Newtonians

From Captain F. L. Tabrah comes the following useful communication:

I was very much interested and pleased to find the excellent discourse on long focus Newtonians by E. K. White in the October issue of the JOURNAL.

Some time ago I built an instrument having a 5-inch, f/15.6 mirror of 2 metres focal length, a peculiar set of figures resulting from designing the speculum to give good results with a set of Huyghenian oculars having field lenses of 1.75 cm. diameter.

The resulting system was quite beyond expectation—with so shallow a curve, parabolization was not attempted, yet definition was excellent.

Many mirrors of f/8 design must certainly exceed the capabilities of the oculars that are often used with them, for the commonly used Huyghenian eyepiece will show serious chromatic aberration if the cone of incident light exceeds an angle of four to five degrees at the focus. As the cone of an f/8 mirror exceeds this value, it is easily understandable that expensive achromatic oculars are necessary for good results, if one insists on f/8 designs.

E. K. White mentioned possible harmful effects of a long closed tube; with a 7½-foot, uninsulated metal tube of 6 inches diameter, there seemed to be a minimum of disturbance.

It is hoped that White's article will draw further comment from others who favour long focus mirrors.

Further comments on this subject are invited. C.A.C.

The Gnomon of Toscanelli

Information is asked regarding the "Gnomon of Toscanelli," which is said to be still in existence in a church in Italy. The present writer has not found any record of such a gnomon, but it appears probable that the person was Paolo dal Pozzo Toscanelli (1397-1482), who was born in Florence and is described as a physician and cosmographer and is said to have been the greatest geographer of his time. Columbus received important information and advice from him. In the church of Santa Croce in Florence are memorials of Paolo Tascanelli and also of Amerigo Vespucci, after whom America was named.

C. A. C.

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